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PHYSIOLOGICAL AND PSYCHOMOTOR EFFECTS OF LOW ALTITUDE AIR COMBAT MANEUVERING

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21. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Naval Air Development Center's Human Centrifuge was used to simulate the in-flight stresses and aircraft maneuvers involved in low altitude, air combat scenarios. The effects of these scenarios on aircrew physiological function and psychomotor performance were studied in depth. The in-flight stresses encountered included a realistic ACM profile, ground effect/high speed or stall buffet, as well as moderate and high intra-cockpit temperatures. Various methods of ameliorating the effects of these stressors were studied		

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simultaneously. These included varying the pilots' seatback angle, with or without concomitant changes in armrest positioning, and decreasing the intra-cockpit temperature to low levels. Analysis of the physiological and psychomotor performance data revealed the following: (1) raising or lowering intra-cockpit temperature, from an ambient level, has a significant effect on the pilots' physiological and psychomotor functions, (2) heart rate provides a good indicator of psychomotor performance under the conditions studied, (3) the effects of buffet were minor compared to changes in intra-cockpit temperature, so far as physiological or performance functions are concerned, (4) a simple adjustment in armrest position, concomitant with seatback angle alterations, produces significant changes in performance capabilities. Details of these and other physiological/performance findings, as well as hematological and biochemical findings, are discussed.

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I N T R O D U C T I O N

Many psychological and physical factors impinge on pilot or aircrew performance, varying as a function of aircraft type or mission (2, 3, 4, 6, 8, 9, 11, 12, 16, 17, 18, 19, 20, 23). Of these, the physical create the most problems for the pilot or aircrewman in terms of fatigue, performance, or mission failure.

Recent improvements in air- and ground-based radar have impacted on both tactical and strategic warfare. In spite of sophisticated Electronic Countermeasures (ECM), prohibitive losses could well occur with high altitude raids. Hence, the low-altitude, high-speed penetration regime must once again be examined. Even here, modern defensive weapons increase the need for alertness and maneuverability, aggravating the stress imposed by basic aerodynamics in this regime (1, 17, 21, 22, 27). It is now possible to ameliorate some of these stressor effects (5, 7, 10, 14, 15, 24, 15, 26).

The U.S. Air Force has expended considerable effort studying the effects of physical stressors in fighter aircraft flying low-level desert sorties (10, 19, 20). It is possible, and perhaps more advantageous in many cases, to study these same stressors in the laboratory environment.

METHODS

APPARATUS

All experiments were conducted using the Naval Air Development Center's Dynamic Flight Simulator and associated equipment, as previously described (3).

SUBJECTS

Four centrifuge-experienced subjects, who were members of the Aircraft and Crew Systems Technology Directorate's Human Volunteer Test Subject Pool, participated in this study. The requirements for entry into the pool included an annual Navy Class I flight physical, complete spinal x-ray series showing no deformities, and satisfactory comprehensive biochemical and psychological profiles. All subjects underwent pre- and post-exposure physical examinations, electrocardiographic monitoring during all G exposures, and weekly biochemical and urine analyses.

EXPERIMENTAL PROCEDURE

This study assessed the effects of four (4) physical stressors: acceleration (ACM), buffet/vibration, cockpit temperatures, and varied seatback angles from the vertical. Also, two armrest positions were used to gather data on the effects of G on the operation of a sidarm controller (See Table (I)). The experimental matrix was designed to include all combinations of stressors presented singly, in pairs, three at a time and all four simultaneously.

The primary performance measure, similar to that used in prior studies, involved a dual-axis compensatory tracking task employing a televised image of an Attitude Director Indicator (ADI). A secondary reaction time task was introduced to "overload" the subjects' performance capabilities. Specifics of both tasks have been discussed previously (3).

TRAINING

Beginning 2½ weeks prior to data collection, the potential subjects practiced the tracking task for 1-1½ hours per day in the gondola of the centrifuge. The task was initially presented at a reduced level of difficulty and for a shorter time than would be finally expected, and as the subjects' performance improved, both task difficulty and duration were increased. All potential subjects continued practicing until they achieved asymptotic performance levels, both while stationary and while under G. At this time, final subject selection was made.

DATA COLLECTION

Each data collection exposure lasted one hour, and each subject underwent 36 exposures, under different sets of experimental conditions. Data were collected as in prior studies (3). All subjects were debriefed both between runs and after egress from the gondola in order to develop subjective impressions of the various test conditions. Additional biomedical information was gathered from subjective questionnaires and worksheets.

R E S U L T S

TOTAL TRACKING ERROR

The effects of mode, run, and condition on total tracking error were covered in a prior publication (3). Intra-cockpit temperatures had a significant effect on tracking error, as shown in Figure (2). Although very high intra-cockpit temperatures significantly increased tracking errors, cooling the cockpit afforded no statistically significant improvement in performance when compared with that obtained under ambient temperatures. The presence of buffet significantly degraded tracking ability irrespective of armrest position. There was a significant difference in tracking error between armrest positions as the temperature was varied. In cold cockpit conditions, the configuration with the armrest always parallel to the floor showed a significantly smaller tracking error than the configuration in which the armrest was constantly perpendicular to the seatback. However, these results are reversed in both the ambient and the hot cockpit environments. Figure (3) shows that buffet caused significant degradations in tracking error in all three seatback angles, and that the buffet affected tracking error progressively more as the seatback angle increased from the vertical. It was also found that 30° seatback angle was the best seatback angle in terms of total tracking error.

RESPONSE TIME

Subject response time was affected by mode in the same way as tracking error, i.e., response time was highest during the ACM. The effect of exposure duration from Run 1 through Run 6, was also previously described (3). The response time was significantly longer under ambient intra-cockpit temperature conditions than under either cold or hot conditions, as can be seen in Figure (2). The parallel armrest position yielded shorter response time than did the perpendicular position. Response time increased as the seatback angle increased from 15° to 60° from the vertical, with buffet conditions lowering response times at all seatback angles. Buffet had the least effect on response time at 30° seatback angle, the absolute response times without buffet, being shortest at 30°, and times at 30° with buffet being very close to those at 15° with buffet.

HEART RATE

The effects of mode, run and seatback angle on heart rate agree with earlier findings (3). Increased intra-cockpit temperatures caused a significant increase in heart rate, as can be seen in Figure (2), whereas no significant difference existed between ambient and cold conditions. The effects of the seatback angles on heart rate from Run 1 through Run 6 are shown in Figure (4). Figure (5) shows the effects of intra-cockpit temperature on heart rate from Run 1 through Run 6. Notice the clear delineations here also among temperatures, particularly the hot environment. Buffet effects on heart rate, relative to runs are seen in Figure (6). It should be noted that seatback angle, cockpit temperature and buffet effects on heart rate are consistent over time (runs).

RELATIONSHIPS AMONG DEPENDENT VARIABLES

Statistical results for the dependent variables of mean heart rate, mean total tracking error, and mean response time are presented in Table (II). These results are presented in terms of variance (r^2) of the means, and correlation coefficients (r) of mean values. The results suggest that it may be possible to use a purely physiological parameter to estimate performance, or vice-versa. This is particularly important in terms of instrumentation if remote testing or flight testing is necessary.

BIOCHEMISTRY

Biochemical analyses done weekly failed to reveal significant abnormal plasma or urine component levels. However, some trends were seen in several of the plasma components. Serum Glutamic-Oxalacetic Transaminase, Lactate Dehydrogenase, Sodium, and Calcium levels all showed increases as the weeks progressed, reaching abnormally high peaks between the 6th and the 7th project weeks. Following this peak, all values returned to the high normal range for the remainder of the project. The sole hematological change seen was a steady decline in white cell count over the time period of the study, with a return to normal values within 1-2 weeks following completion of the project.

DISCUSSION

Many of the results from this study confirm those from earlier simulations of attack/fighter (VA/VF) conditions. The very complex interactions among some of the dependent variables, particularly heart rate, total tracking error, and response time, have occurred previously, but a detailed explanation of the interactions is still not forthcoming. Performance and physiological decrements from Run 1 to Run 6 when matched with subjective comments definitely reflect both the onset and the increase in fatigue as runs continue.

It is interesting to note that although the high intra-cockpit temperatures had a severe effect on subject performance and physiological condition, cooling the cockpit below ambient did not show any improvement in performance or physiological condition as might possibly be expected. Armrest position was found to be important to performance, relative to intra-cockpit temperature, since having the armrest perpendicular to the seatback resulted in significantly lower tracking errors than the perpetually parallel armrest position in both ambient and hot conditions. The performance reversal in the cold environment is felt to be due to the coldness of the armrest as the entire forearm lies on the armrest in the perpendicular armrest position, while in the parallel armrest position, only the wrist contacts it.

The significantly greater effect of buffet as seatback angles increased from the vertical can be explained anatomically, and this is a matter of major importance. The man is restrained by his harness, etc, and cannot move, but his internal organs and his head can move. These factors create chest discomfort as well as blurring of vision, neither of which is conducive to good performance. Once again, the data have shown that at a 30° seatback angle, performance is better than at either 15° or 60° from the vertical, particularly under the ACM. Thus the ostensible paradox remains that although performance is enhanced at a 30° seatback angle, heart rate is higher than at a 60° seatback angle.

Changes in response time measurements were similar to those of tracking error, giving two potential methods of forecasting performance, using only one parameter.

Heart rate data also confirmed previously collected data, in terms of the effects of buffet, time given as Run 1 through Run 6, and high intra-cockpit temperatures.

In addition, new information was found concerning the effects on performance and physiological well-being of lowering the intra-cockpit temperature and adjusting the armrest position. In aircraft exhibiting cockpit layouts similar to that used in this study, minor changes in such things as armrest position or intra-cockpit temperature may pay handsome dividends.

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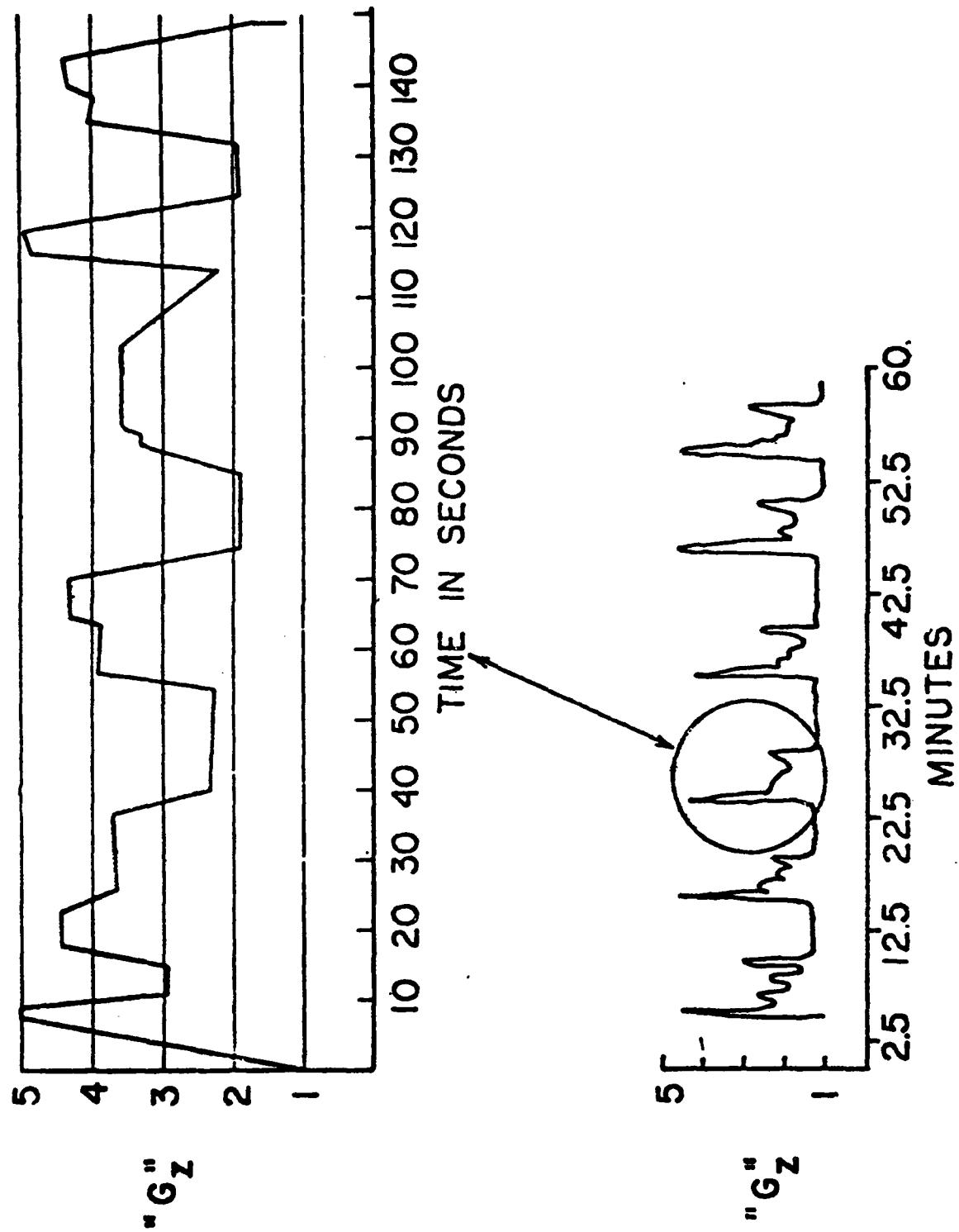


Figure 1 - Air Combat Maneuver (ACM) used in the study

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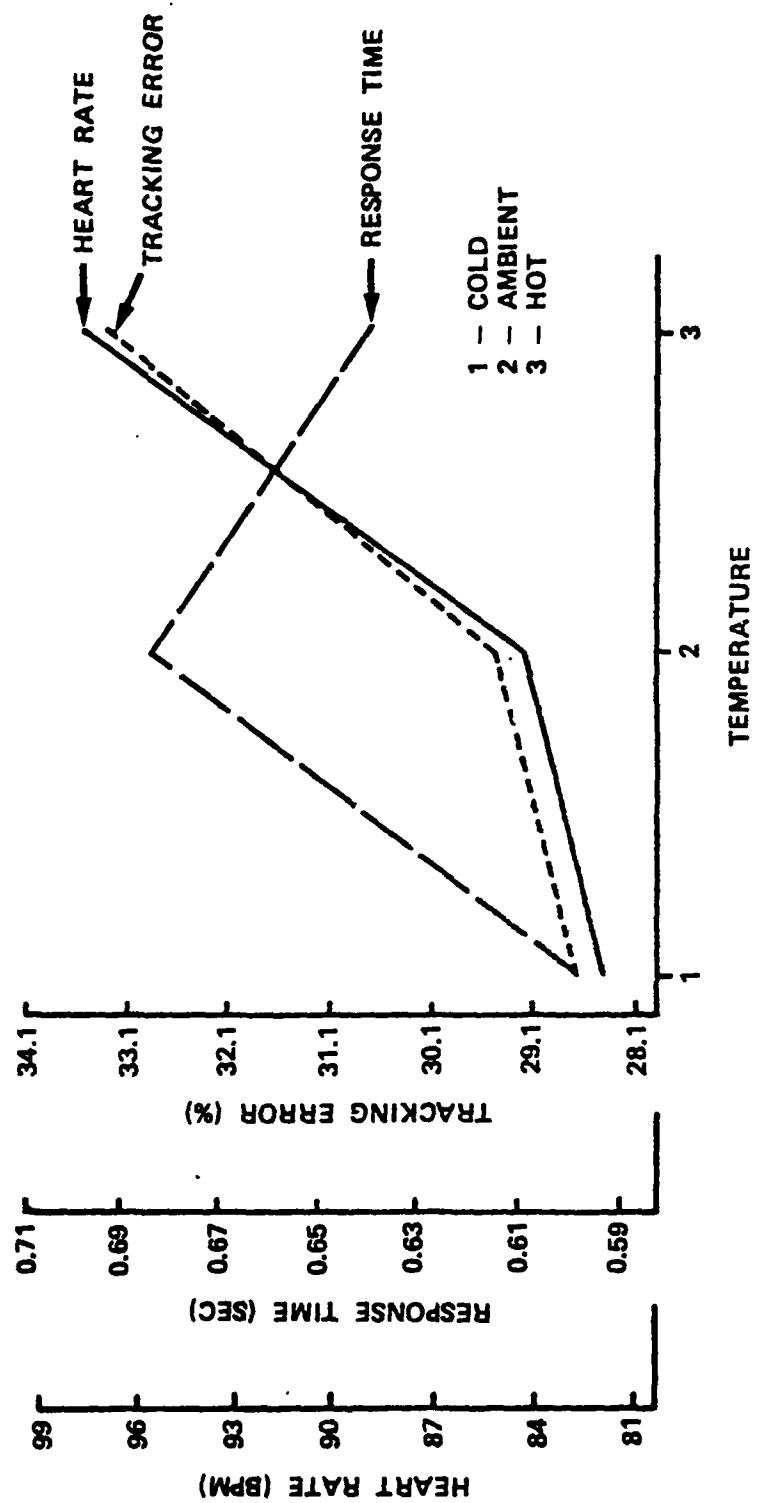


Figure 2 - Temperature Effects on Parameters

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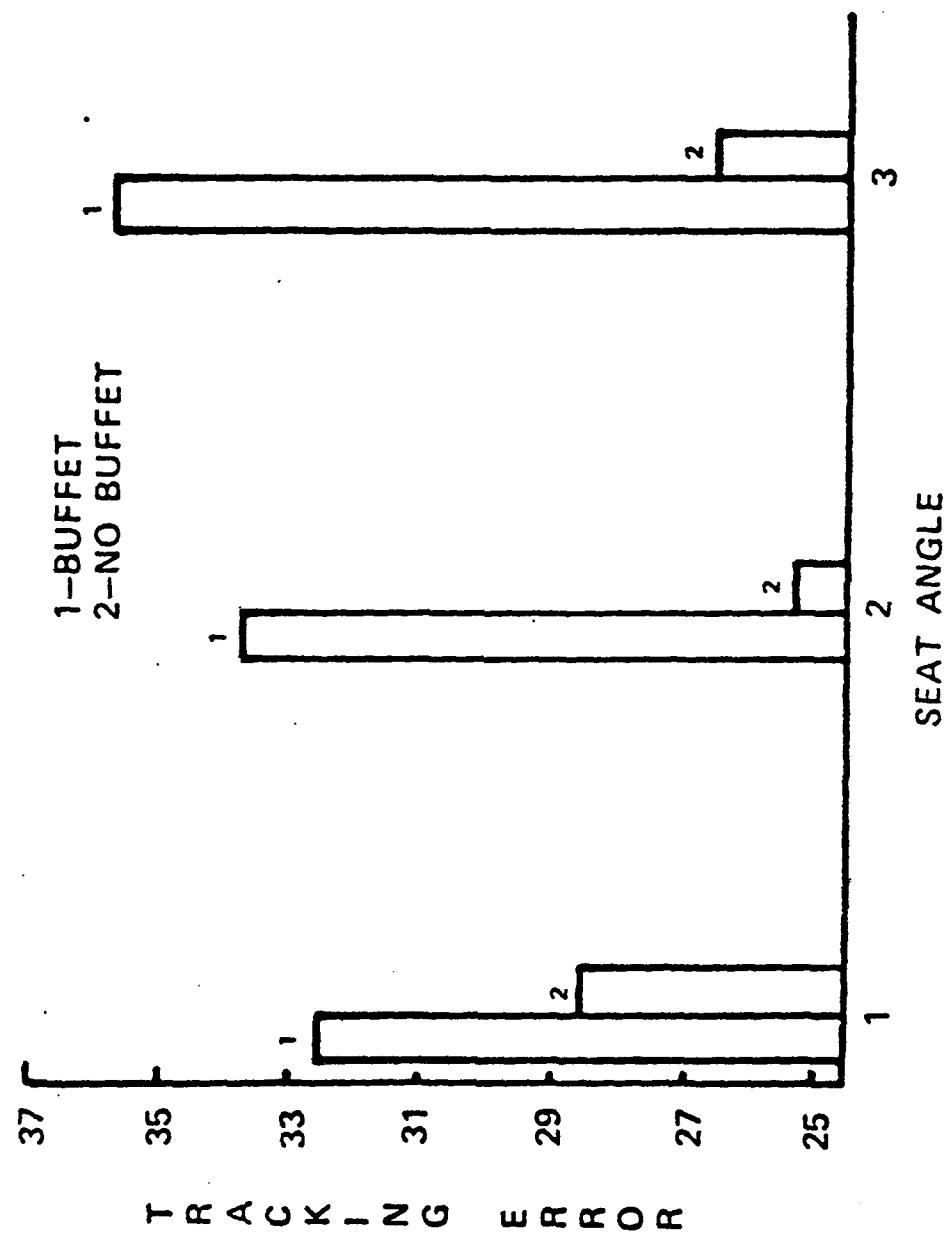


Figure 3 - Mean Tracking Error vs. Seatback Angle, as a function of Buffet

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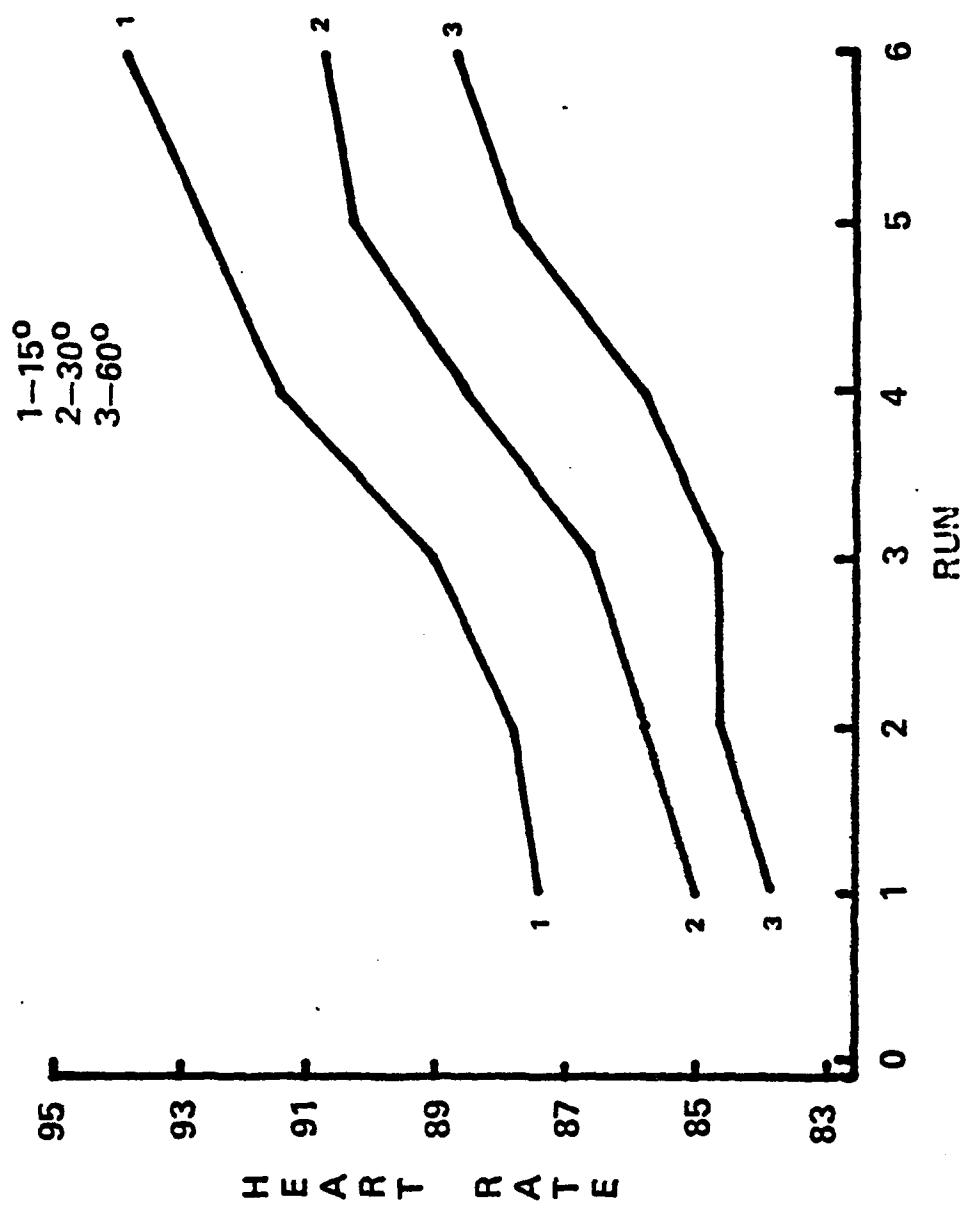


Figure 4 - Mean Heart Rate vs. Run, as a function of Seatback Angle

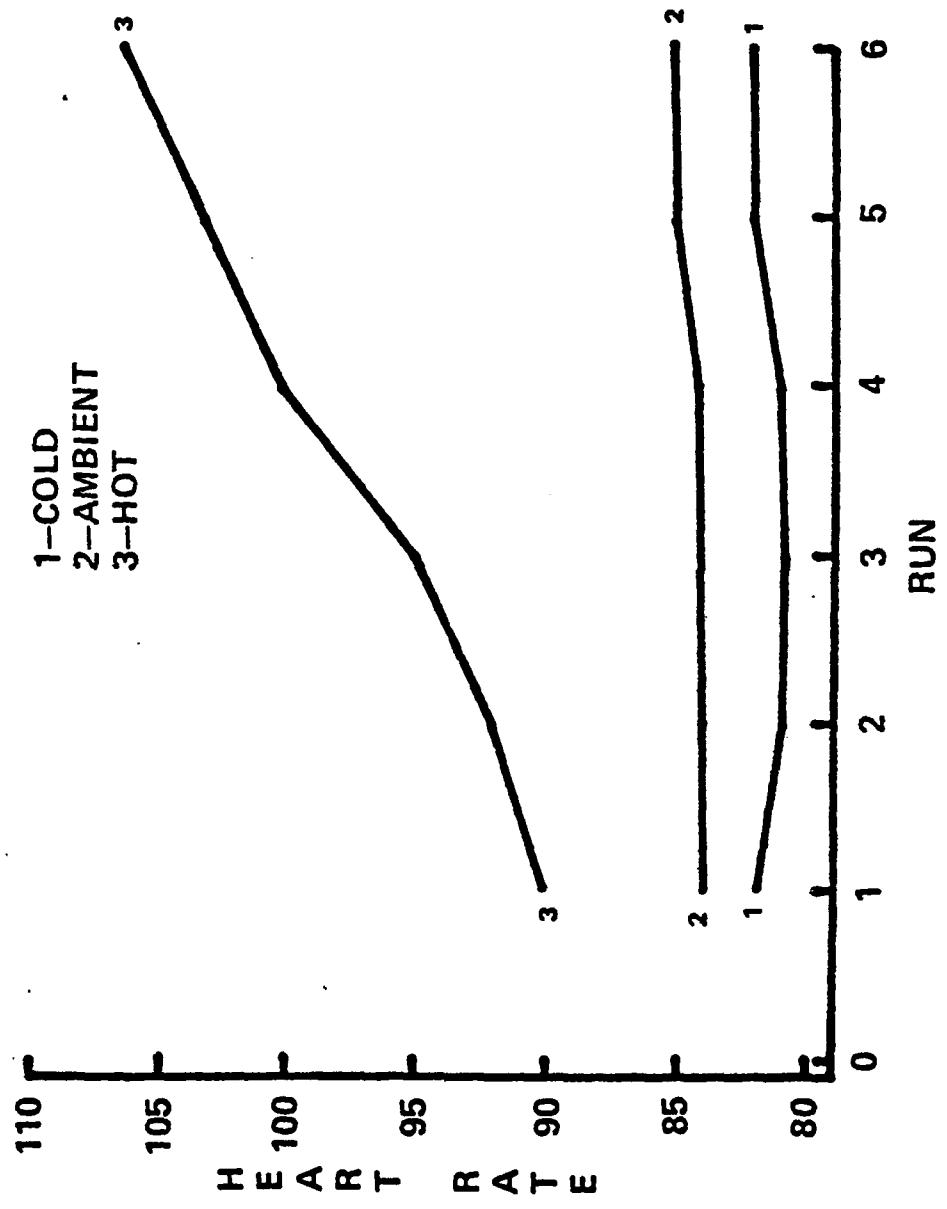


Figure 5 - Mean Heart Rate vs. Run, as a function of Intra-cockpit Temperature

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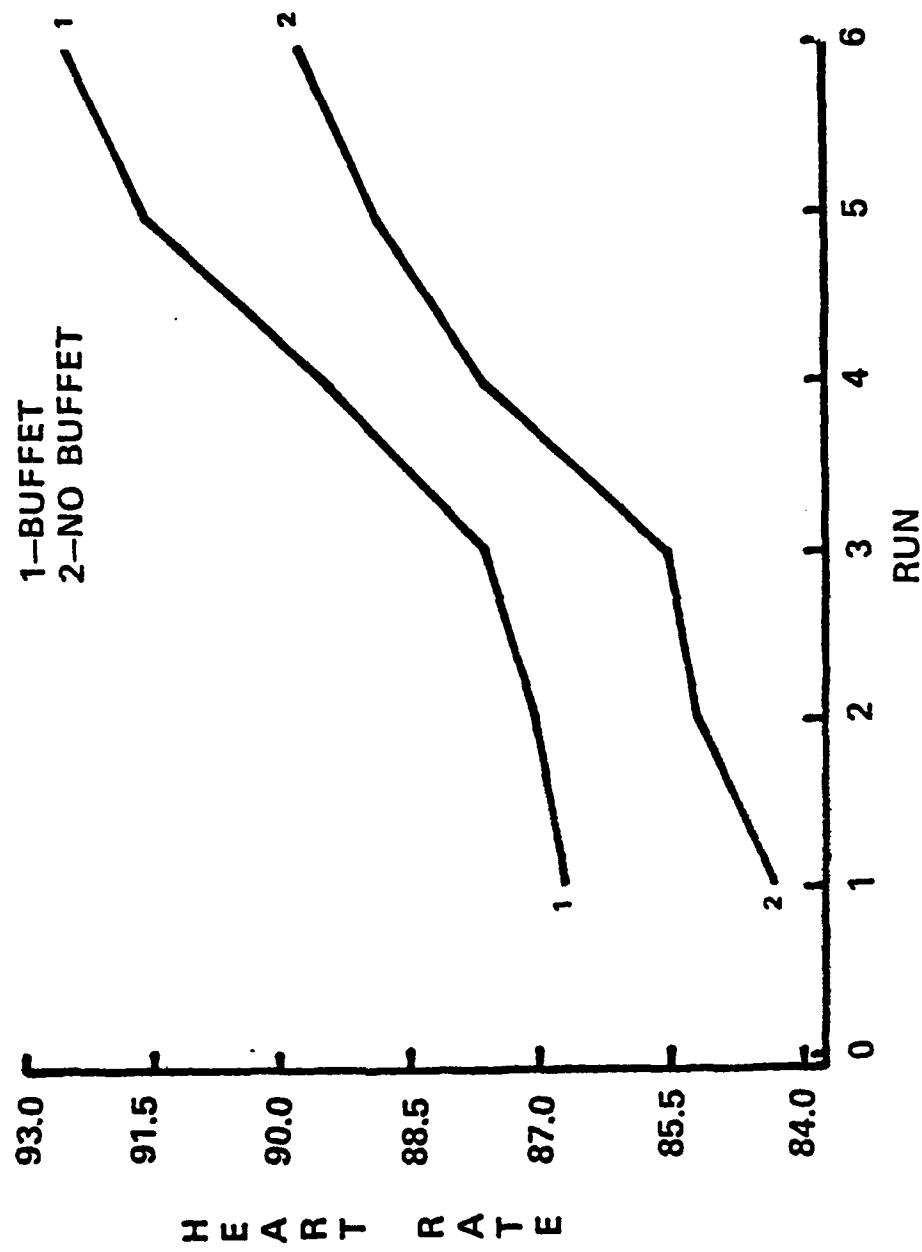


Figure 6 - Mean Heart Rate vs. Run, as a function of Buffet

T A B L E I

STRESSES STUDIED

Acceleration	- ACM
Vibration/Buffet	- 10 Hz, 0.2 G zero-to-peak sinewave
Cockpit temperatures	- 12°C - 15.5°C (cold) - 23.8°C - 26.7°C (ambient) - 48°C - 51°C (hot)
Seatback Angles	- 15° from vertical - 30° from vertical - 60° from vertical
Armrest Positions	- armrest parallel to floor regardless of seatback angle - armrest perpendicular to seatback regardless of seatback angle

T A B L E I I

RELATIONSHIPS AMONG VARIABLES

	<u>r</u>	<u>r²</u>	(explained percent of variance of means)
Mean Tracking Error (TE) vs Mean Response Time (RT)	.939	.882	
Mean Heart Rate (HR) vs Mean Tracking Error (TE)	.669	.448	
Mean Heart Rate (HR) vs Mean Response Time (RT)	.667	.458	
MTE vs MRT vs MHR		R=.940 R=.883	

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